Structure and wetland classification status of a Central Ohio riparian forest

James S. Marshall

Evolution, Ecology, and Organismal Biology, The Ohio State University

Introduction

A forested system with inundation during the growing season that saturates the root zone and promotes tree species with adaptations to flooding is considered a bottomland hardwood forest (Mitsch and Gosselink, 2000). Rivers usually provide the water, making this system especially prevalent in riparian areas. United States legislation, however, does not specify bottomland hardwood forest as a wetland entitled to federal protection. For legal protection a wetland must have hydric soils and hydrophytic vegetation (Mitsch and Gosselink, 2000).

Most trees fare poorly in wetland situations (Resource Management Group, 1999). Typical trees occurring in riparian areas include: silver maple (*Acer saccharinum* L.), sycamore (*Platanus occidentalis* L.), green ash (*Fraxinus pennsylvanica* Marshall), box elder (*Acer negundo* L.), hackberry (*Celtis occidentalis* L.), and American elm (*Ulmus americana* L.). All of these trees would also be expected in Ohio (Gleason and Cronquist, 1991). If a forest is also a wetland, then the tree species composition should be dominated by wetland-adapted species.

Knorr (1998) also mentions that bottomland forests often, but not always, have higher productivity. One could therefore expect higher tree densities in riparian areas most influenced by flooding. Fewer species should be able to tolerate frequent flooding near the river, so the species diversity should also be lower in that area (Johnson et al., 1976). The proportion of wetland adapted species should also decline as one moves away from the source of flood waters.

Hypothesizing that the Olentangy River Wetland Research Park (ORWRP) forest is a bottomland hardwood forest, this study investigates a series of predictions that follow such a hypothesis. The forest should be dominated by trees adapted to flooding. As one moves away from the edge of the river, tree density and the proportion of wetland-adapted species should decrease, and the tree species diversity should increase. If the ORWRP forest is a wetland, there should be evidence supporting these predictions.

Methods

Study Area

This study was conducted in the forest adjacent to the Olentangy River within the bounds of the Olentangy River Wetland Research Park. The park is located in the north part of The Ohio State University campus in Columbus, Ohio. The forest runs west to east along the north end of the park and then north to south on the east side of the park. Forest width ranges from about 18 m to over 80 m. The forest stretches about 700 m from a control structure north of the park to a bridge south of the park. A levee has run along the bank for the last century or so.

Data Collection

Forest vegetation was surveyed along 550 m of the Olentangy River starting at the north control structure. Transects started perpendicular to the river at random points every 10 to 50 m along the river bank. Points were established every 10 m along those transects. The research team surveyed four trees at each point using a point-quarter method (Cottam and Curtis, 1956). The team chose one tree in each quadrant around a point and measured the distance to each tree, as well as its diameter at breast height (dbh). The survey included 20 transects with a total of 86 points at which were measured 328 different trees.

Data Analysis

The density of all species is calculated by dividing the total number of square meters in a hectare by the squared average distance to a tree. The density of an individual species was then the density of all species times the percentage of stems represented by that species. Relative densities were also calculated for each species by dividing each individual density by the sum of all densities.

Each dbh is converted into basal area by squaring the dbh and multiplying by one-quarter pi. The average basal area of a given species was then the sum of all basal areas for that species divided by the number of stems of that species. Multiplying mean basal area of a species and its density gave a measure of dominance. Relative dominance was then individual species dominance divided by the sum of all dominances.

The proportion of the 86 points at which the team recorded a certain species was the frequency of occurrence for that species. Relative frequency was the individual frequency divided by the sum of all frequencies. The sum of relative density, dominance, and frequency for each species gives the importance value for each species (Whittaker, 1967). The importance value gives a somewhat objective measure of forest species composition.

A wetland plant guide (Resource Management Group,

1999) was used to produce a wetland index for the forest. The values for this index are listed in Table 1. The number of stems of each species was multiplied by its respective index numbers. The result was then summed for all species and divided by the total number of tree stems to give a total forest wetland index. To weight each tree by its relative significance, the individual species wetland index values were multiplied by their importance values and the total forest wetland index recalculated.

Diversity was calculated using the Shannon-Weiner diversity index (Johnson et al., 1976). After calculating the proportion of total stems represented by each species, one then multiplies the natural log of each proportion by the proportion itself. The sum of these numbers for all species gives the diversity index.

The density, wetland index, and diversity for all trees were calculated at the following distances from the river: 10, 20, 30, 40, 50, 60, and 70 m. The relationships between distance from the river and density, wetland index, and diversity were then assessed using simple regressions. In each case, distance from the river was the independent variable. Density was related to distance by a quadratic relationship; the other two variables had a linear relationship to distance. Minitab version 13 was used for these regressions. All of the equations are listed in Appendix 1.

Results

Total density of all trees in the ORWRP was 900.9 trees ha^{-1}. Box elder had the highest density at 260.9 trees ha^{-1}. Ohio buckeye (*Aesculus glabra* Willd.) had the next highest density with 236.2 trees ha^{-1}. Other trees in order of decreasing density were hackberry, pawpaw (*Asimina triloba* (L.) Dunal.), red mulberry (*Morus rubra* L.), black walnut (*Juglans nigra* L.), and American elm (Table 2).

Importance values tended to confirm the densities. Box elder had the largest importance value (74.3). Ohio buckeye had the next highest value of 57.5, this was followed by sycamore (26.7). Other important trees in descending order were hackberry, red mulberry, eastern cottonwood (*Populus deltoides* Marshall), pawpaw, and black walnut (Table 3).

Table 1. Wetland index values used for calculating the wetland index of the Olentangy River Wetland Research Park, based on Resource Management Group (1999).

%Occurrence in Wetlands	Wetland Index Value
>99	+2.0
90-99	+1.5
70-89	+1.0
55-69	+0.5
45-54	0.0
30-44	-0.5
10-29	-1.0
1-9	-1.5
<1	-2.0

The average unweighted wetland index value was -0.282. An average tree in this forest therefore typically occurs in a wetland less than 50 percent of the time. Weighting the index by importance value gave a number of -0.473. By this measure the average tree occurs in wetlands about a third of the time.

Tree density was highest 10 m from the river (1126.8 trees ha^{-1}) and 70 m from the river (1404.8 trees ha^{-1}). The relationship between distance and tree density was a highly significant positive quadratic function ($R2 = 0.859$, $p = 0.020$). Diversity decreased significantly as distance from the river increased ($R2 = 0.716$, $p = 0.016$). The wetland index increased as one moved away from the river, but that increase was only slightly significant ($R2 = 0.479$, $p = 0.085$) (Table 4).

Discussion

Each of the predictions was unsupported, leading one to conclude that the evidence does not support calling the ORWRP forest a wetland. Based on the wetland index, the trees of this forest are more likely to be found in an upland than in a wetland. Tree density and wetland index actually increased as one moved away from the river, and species diversity decreased away from the river.

This study found much higher densities than were reported by Bouchard and Mitsch (1999). Their survey covered 700

Table 2. Densities of tree species recorded in the Olentangy River Wetland Research Park forest in the fall of 2000.

Species	Density (trees ha^{-1})
Box Elder	260.9
Ohio Buckeye	236.2
Hackberry	87.9
Pawpaw	79.7
Red Mulberry	65.9
Black Walnut	41.2
American Elm	24.7
Eastern Cottonwood	22.0
Sycamore	19.7
Black Cherry	11.0
Osage-orange	8.2
Silver Maple	8.2
Green Ash	5.5
White Ash	5.5
Willow sp.	5.5
Apple	2.8
Black Locust	2.8
Catalpa	2.8
Crabapple	2.8
Hawthorn	2.8
Red Oak	2.8
Viburnum sp.	2.8

Table 3. Importance values of tree species recorded in the Olentangy River Wetland Research Park forest in the fall of 2000.

Species	Importance Value
Box Elder	74.3
Ohio Buckeye	57.5
Sycamore	26.7
Hackberry	26.4
Red Mulberry	17.2
Eastern Cottonwood	14.3
Pawpaw	14.1
Black Walnut	13.1
American Elm	7.5
Silver Maple	4.5
Willow sp.	4.0
Black Cherry	2.7
Osage-orange	2.3
White Ash	1.4
Green Ash	1.4
Crabapple	0.9
Red Oak	0.8
Apple	0.7
Black Locust	0.7
Catalpa	0.7
Viburnum sp.	0.7
Hawthorn	0.7

m of forest including the 150 m not included in this survey. This last stretch was an area of lower than average density and may account for some of the discrepancy. Their densities for individual species, while lower than this study's, were similarly ranked by species. They also found box elder followed by Ohio buckeye to have the highest densities, and they had similarly high densities for hackberry, pawpaw, red mulberry, and black walnut if not necessarily in the same order. Flowering dogwood (*Cornus florida* L.) was an important species in their study that was unrecorded in this study.

Knorr (1998) also did a study of ORWRP forest vegetation and calculated importance values. He also found box elder and Ohio buckeye to be the most important trees in this forest. Unlike Bouchard and Mitsch (1999) and this study, he found osage-orange (*Maclura pomifera* (Raf.) C.K. Schneider) to be an important species. Red mulberry, American elm, and pawpaw all had high values; hackberry was surprisingly under-represented. The current study found osage-orange to be prevalent at the edge farthest from the river, probably part of an old fence row. This suggests that Knorr's survey may have been biased towards this edge, accounting for some of the departures from the other studies.

Studies from other bottomland forests in the United States have many of the same species as the ORWRP, although different species may have been dominants. Brown and Peterson (1983) studied an Illinois bottomland with a lower tree density than either this study or Bouchard and Mitsch (1999). Silver maple and green ash were the most important species in their system; but American elm, sycamore, box elder, and red mulberry were also significant components. Bell's study (1974) showed that silver maple dominated forests with high flooding frequencies, but in less flooded areas more typical of the ORWRP, American elm and hackberry became more important. Johnson et al. (1976) also found box elder and American elm to be significant components of bottomland forest. Dutch elm disease has reduced the elm population of the ORWRP, and this may be why box elder has become such a prominent species.

Vegetation is a major wetland indicator (Mitsch and Gosselink, 2000). An unweighted wetland index was calculated from the Bouchard and Mitsch study (1999). Their value of -0.370 is lower than this study's result, suggesting that the forest is shifting towards a wetland. The levee along the Olentangy River was opened in four places in 2000. Although that does not account for the shift, the forest is flooded regularly (Acton et al., 1998) which over time will shift tree composition towards flood-tolerant species. Ilick (1999) found evidence of such a shift with more flood-tolerant box elder sapling density increasing at a faster rate than that of the less tolerant pawpaw or Ohio buckeye saplings.

The vegetation confirms earlier work indicating that although the system is flooded, it cannot yet be considered a jurisdictional wetland. Geist's (1998) survey of 15 soil samples from the forest found only two samples with a chroma of two and none with a lower chroma. The soil also had no hydric indicators such as oxidized rhizospheres. At present, both vegetation and soil indicate against a wetland.

Table 4. Tree density, wetland index value, and diversity at different distances from the Olentangy River in the Olentangy River Wetland Research Park in the fall of 2000.

Distance (m)	Tree Density (trees ha^{-1})	Wetland Index	Diversity index
10	1127	-0.487	1.979
20	828	-0.188	1.948
30	823	-0.343	2.104
40	663	-0.130	1.745
50	939	-0.212	1.870
60	884	-0.227	1.226
70	1405	-0.111	0.828

The predictions regarding relationships between various factors and distance from the river were also incorrect. Density may not be a reliable indicator of higher productivity (Knorr, 1998). The data did show higher vegetation densities at the edges of the forest. Gates and Gysel (1978) stated that density tends to increase at habitat edges. Density may therefore decrease as one moves away from any edge, obscuring relationships attributable to flooding.

Diversity is also higher at edges, which may explain the decrease away from the river's edge. Since flooding at the ORWRP is insufficient to favor wetland vegetation, the flood-intolerant species may not yet be eliminated from the areas near the river. Johnson et al. (1976) found very low diversity in North Dakota floodplain forests and reported mesic forest diversity values that are similar to the values reported in this study. This could be another indication of the ORWRP forest not yet being a wetland.

Finally, the increasing wetland index as one moves away from the river is puzzling. It suggests that flood water leaves the river edge quickly and remains standing until evaporated in the forest interior. Without a more detailed study of the forest hydrology, further comments cannot be made except to note that the breaks in the levee should alter such a pattern if it exists. Although not currently a wetland, the areas near the breaks should be developing hydric soils and vegetation over the next few years.

Acknowledgments

I would like to thank my partners in this study (Herrs Amato, Ware, and Westerfield) for enduring long hours of survey tedium to gather these results. Thanks to Dr. Mitsch for providing the opportunity for this study. Dr. Bouchard also pointed me towards valuable past studies. Finally, thanks to Lori Winchester for all of her support.

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Appendix 1. Equations used in calculations.

Variables
Di = density of species i
d = average distance from a sample point to a tree
ni = number of species i
nT = total number of trees
RDi = relative density of species i
I = total number of species
BAi = average basal area of species i
DOi = dominance of species i
RDOi = relative dominance of species i
Fi = frequency of species i
RFi = relative frequency of species i
pi = number of sample points with species i
IVi = importance value of species i
H= = diversity
ri = proportion of total stems represented by species i

Equations
Di = (d2 / 10,000 m2) (ni / nT)
RDi = Di / _ Di   for i = 1 to I
BAi = _ (π (dbhi)2 / 4) / ni   for i = 1 to ni
BAi * Di = DOi
RDOi = DOi / _ DOi   for i = 1 to I
Fi = pi / 86
RFi = Fi / _ Fi   for i = 1 to I
IVi = (RDi + RDOi + RFi) * 100
H= = _ ri ln ri